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7 S P E C I F I C A T I O N

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10 TITLE OF THE INVENTION

11
12 THREE-CELL WIRELESS COMMUNICATION SYSTEM

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14 BACKGROUND OF THE INVENTION

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16 1. Field of the Invention

17
18 This invention relates to cellular radio communication.
19 More specifically, this invention relates to a cellular radio
20 communication system including a repeated pattern of three cells.

21
22 2. Description of Related Art

23
24 In a wireless communication system it is generally
25 necessary for a receiver to distinguish between those signals in
26 its operating region that it should accept and those it should
27 reject. A common method in the art is frequency division (FDMA),
28 in which a separate frequency is assigned to each communication

1 channel. Another common method in the art is time division
2 (TDMA), in which a separate timeslot in a periodic time frame is
3 assigned to each communication channel.

4
5 One problem which has arisen in the art is that
6 contiguous coverage of a large area using radio communication has
7 required a cellular configuration with a large number of cells,
8 and thus with only a small number of frequencies available per
9 cell. In an FDMA system, all relatively proximate cells, not
10 just adjacent cells, must operate on different frequencies, and
11 frequencies may be reused only sufficiently far away that
12 stations using those frequencies no longer interfere. In
13 general, with homogenous conditions and equal-power transmitters,
14 the distance between perimeters of like-frequency cells must be
15 at least two to three times the diameter of a single cell. This
16 had led to a seven-cell configuration now in common use for
17 cellular networks.

18
19 Another problem which has arisen in the art when the
20 cells are disposed in a three-dimensional configuration,
21 particularly in low-power applications where many transmitters
22 are in close proximity. In addition to avoiding interference
23 from close transmitters, these systems may require complex
24 techniques for handing off mobile stations from one cell to
25 another, and for reassigning unused frequencies. This makes the
26 physical location of each cell's central station critical, and
27 thus requires careful coordination of an entire communication
28 system layout.

U.S. Patent No. 4,790,000 exemplifies the art.

Accordingly, an object of this invention is to provide a wireless communication system including a pattern having a reduced number of cells. Other and further objects of this invention are to provide a communication system which is less complex, which allows for reduced cell size, which can easily be extended from a two-dimensional to a three-dimensional configuration, which can reject interference, and which allows independent installation of multiple communication systems.

SUMMARY OF THE INVENTION

The invention provides a wireless communication system including a repeated pattern of cells, in which base station transmitters and user station transmitters for each cell may be assigned a spread-spectrum code for modulating radio signal communication in that cell. Accordingly, radio signals used in that cell are spread across a bandwidth sufficiently wide that both base station receivers and user station receivers in an adjacent cell may distinguish communication which originates in one cell from another. (Preferably, adjacent cells may use distinguishable frequencies and distinguishable codes, but it is sufficient if adjacent cells use distinguishable frequencies and identical codes.) A repeated pattern of cells allows the codes each to be reused in a plurality of cells.

1 In a preferred embodiment, a limited number (three is
2 preferred) of spread-spectrum codes may be selected for minimal
3 cross-correlation attribute, and the cells may be arranged in a
4 repeated pattern of three cells, as shown in figure 1. Station
5 ID information may be included with data communication messages
6 so that base stations and user stations may distinguish senders
7 and address recipients. Mobile user stations may be handed off
8 between base stations which they move from one cell to the next.

9
10 In a preferred embodiment, codes may be assigned
11 dynamically for each cell by each of a plurality of independent
12 communication systems, after accounting for use by other systems.
13 Preferably, if a control station for a second system determines
14 that two codes are in use closest to it, it may select a third
15 code for use in its nearest cell, and dynamically assign codes
16 for other cells to account for that initial assignment. A
17 control station for the first system may also dynamically
18 reassign codes to account for the presence of the second system.
19 Preferably, this technique may also be applied to a three-
20 dimensional configuration of cells.

21
22 In a preferred embodiment, time division and frequency
23 division reduce the potential for interference between station
24 transmitters. In a preferred embodiment, each independent
25 communication system may dynamically assign (and reassign) a
26 frequency or frequencies to use from a limited number (three is
27 preferred) of frequencies, after accounting for use by other
28

1 systems, similarly to the manner in which codes are dynamically
2 assigned and reassigned from a limited number of codes.

3 4 BRIEF DESCRIPTION OF THE DRAWINGS

5
6 Figure 1 shows a repeated pattern of three cells.

7
8 Figure 2 shows a wireless communication system.

9
10 Figure 3 shows a region with a plurality of independent
11 communication systems.

12 13 DESCRIPTION OF THE PREFERRED EMBODIMENT

14
15 Figure 1 shows a repeated pattern of three cells.

16
17 Figure 2 shows a wireless communication system.

18
19 A wireless communication system 201 for communication
20 among a plurality of user stations 202 includes a plurality of
21 cells 203, each with a base station 204, typically located at the
22 center of the cell 203. Each station (both the base stations 204
23 and the user stations 202) generally comprises a receiver and a
24 transmitter.

25
26 In a preferred embodiment, a control station 205 (also
27 comprising a receiver and a transmitter) manages the resources of
28 the system 201. The control station 205 assigns the base station

1 204 transmitters and user station 202 transmitters in each cell
2 203 a spread-spectrum code for modulating radio signal
3 communication in that cell 203. Accordingly, radio signals used
4 in that cell 203 are spread across a bandwidth sufficiently wide
5 that both base station 204 receivers and user station 202
6 receivers in an adjacent cell 206 may distinguish communication
7 which originates in the first cell 203 from communication which
8 originates in the adjacent cell 206.

9
10 Preferably, adjacent cells 203 may use distinguishable
11 frequencies and distinguishable codes, but it is sufficient if
12 adjacent cells 203 use distinguishable frequencies and identical
13 codes. Thus, cells 203 which are separated by an intervening
14 cell 203 may use the same frequency and a distinguishable code,
15 so that frequencies may be reused in a tightly packed repeated
16 pattern. As noted herein, spread-spectrum codes which are highly
17 orthogonal are more easily distinguishable and therefore
18 preferred.

19
20 The cells 203 may be disposed in the repeated pattern
21 shown in figure 1. A cell 203 will be in one of three classes: a
22 first class A 207, a second class B 208, or a third class C 209.
23 No cell 203 of class A 207 is adjacent to any other cell 203 of
24 class A 207, no cell 203 of class B 208 is adjacent to any other
25 cell 203 of class B 208, and no cell 203 of class C 209 is
26 adjacent to any other cell 203 of class C 209. In a preferred
27 embodiment, three spread-spectrum codes may be preselected, such
28

1 as for minimal cross correlation attribute, and the such code
2 assigned to each class of cells 203.

3
4 However, it would be clear to one of ordinary skill in
5 the art, after perusal of the specification, drawings and claims
6 herein, that alternative arrangements of the cells 203 would also
7 be workable. For example, the cells 203 might be arranged in a
8 different pattern. Alternatively, each base station 204 and each
9 user station 202 may be assigned a separate code, which may then
10 be used to identify that station. Hybrids between these two
11 extremes, such as assigning a common code to a designated class
12 of stations, may be preferred where circumstances indicate an
13 advantage. It would be clear to one of ordinary skill in the
14 art, that such alternatives would be workable, and are within the
15 scope and spirit of the invention.

16
17 In a preferred embodiment, only a single code is used
18 for all base stations 204 and user stations 202 in a single cell
19 203. A message 210 which is transmitted by a base station 204 or
20 a user station 202 may comprise a portion 211 which comprises
21 station ID information, such as a unique ID for the transmitting
22 station. This allows base stations 204 and user stations 202 to
23 distinguish the sender and to address the recipient(s) of the
24 message 210.

25
26 When a mobile user station 202 exits the first cell 203
27 and enters the adjacent cell 206, the user station 202 is "handed
28 off" from the first cell 203 to the adjacent cell 206, as is well

known in the art. Determining when the user station 202 should be handed off may be achieved in one of several ways, including measures of signal strength, bit error rate, cross-correlation interference, measurement of distance based on arrival time or position locationing, and other techniques which are well known in the art. Alternatively, the mobile user station 202 may simply lose communication with the base station 204 for the first cell 203 and re-establish communication with the base station 204 for the adjacent cell 206, also by means of techniques which are well known in the art.

Figure 3 shows a region with a plurality of independent communication systems.

In a preferred embodiment, a single region 301 may comprise both a first system 302 and a second system 303 for wireless communication. The cells 203 of the first system 302 will be distinct from the cells 203 of the second system 303. Rather than disposing the cells 203 of either the first system 302 or the second system 303 in repeated patterns which may clash, the cells 203 each may have a code which is dynamically assigned (or reassigned), with the first system 302 accounting for use by the second system 303 and vice versa.

In a preferred embodiment, the first system 302 may assign a code to each of the cells 203 based on a limited set of codes and a repeated pattern such as that in figure 1. The second system 303 may then determine those codes in the limited

1 set which are in closest use to the control station 205 for the
2 second system 303. The second system 303 may then select one of
3 the remaining codes, and assign the selected code to the cell 203
4 comprising its control station 205. The control station 205 for
5 the second system 303 may then assign a code to each of the cells
6 203 in the second system 303 based on the same limited set of
7 codes and a repeated pattern such as that in figure 1. In a
8 preferred embodiment, the limited set may comprise three codes,
9 and up to two such closest codes may be determined.

10
11 More generally, the first system 302 and the second
12 system 303 may each assign a code to each of the cells 203 in
13 their respective systems, based on a limited set of common codes.
14 For each of the cells 203, either the first system 302 or the
15 second system 303 will manage the base station 204 for that cell
16 203, and thus be in control of that cell 203. The system in
17 control of that cell 203 may dynamically determine those codes
18 from the limited set which are in closest use to the base station
19 204 for the cell 203, select one of the remaining codes, and
20 assign the selected code to the cell 203.

21
22 It would be clear to one of ordinary skill in the art,
23 after perusal of the specification, drawings and claims herein,
24 that application of the disclosed techniques for dynamic
25 assignment (and reassignment) of codes to cells 203 to a three-
26 dimensional configuration of cells 203, would be workable, and is
27 within the scope and spirit of the invention.
28

1 In a preferred embodiment, time division is also used.
2 A pulsed-transmitter based system, a minimized number of pulses,
3 and a minimized duration of each pulse reduce the probability of
4 collisions, as is well known in the art. Multiple transmitters
5 may thus all use the same code and the same frequency, as is well
6 known in the art.

7
8 In a preferred embodiment, frequency division is also
9 used. Three techniques are disclosed; the third is a preferred
10 embodiment for many envisioned environments. However, it would
11 be clear to one of ordinary skill in the art, after perusal of
12 the specification, drawings and claims herein, that other
13 techniques would be workable, and are within the scope and spirit
14 of the invention. It would also be clear to one of ordinary
15 skill that these techniques may be used with spread-spectrum
16 frequency offset techniques instead of frequency division.

17
18 (1) If the region 301 comprises only the first system
19 302 alone, two frequencies may be used. All of the base stations
20 204 use a first frequency, while all of the user stations 202 use
21 a second frequency. Accordingly, all of the base stations 204
22 can receive signals from all of the user stations 202, but the
23 use of multiple sufficiently orthogonal spread-spectrum codes
24 allows each base station 204 to reject signals from outside its
25 own cell 203. (Spread-spectrum codes which are highly orthogonal
26 are preferred.) The first frequency and the second frequency
27 must be sufficiently separated so that interference does not
28 occur.

1
2 (2) If the region 301 comprises both the first system
3 302 and the second system 303, frequencies may be assigned
4 dynamically. All of the base station 204 transmitters in each
5 system use a first frequency, selected from a limited set. All
6 of the user station 202 transmitters in each system use a second
7 frequency, also selected from a limited set, not necessarily the
8 same set. Moreover, each system may dynamically assign and
9 reassign frequencies in like manner as disclosed above for
10 dynamic assignment and reassignment of codes. In like manner as
11 to codes, in a preferred embodiment, the limited set may comprise
12 three frequencies, and up to two such closest frequencies may be
13 determined.

14
15 (3) If the region 301 comprises both the first system
16 302 and the second system 303, frequencies may be assigned
17 dynamically. All of the base station 204 transmitters and all of
18 the user station 202 transmitters in each cell 203 use a single
19 frequency, selected from a limited set. Each base station 204
20 dynamically determines those frequencies from the limited set
21 which are in closest use to it, and selects one of the remaining
22 frequencies for use in the cell 203. The base station 204
23 transmitters and the user station 202 transmitters may be time-
24 division duplexed. (Time-division duplexing is well known in the
25 art.) In like manner as to codes, in a preferred embodiment, the
26 limited set may comprise three frequencies, and up to two such
27 closest frequencies may be determined.

12

1 The amount of separation required between frequencies
2 (while also using code-division and time-division techniques) is
3 dependent upon distance between the user stations 202 in each
4 cell 203, as well as upon the technique used for modulation and
5 demodulation encoded signals. As is well known in the art, some
6 modulation techniques allow for overlapping wideband signals
7 whose center frequencies are offset by a minimum amount necessary
8 to distinguish between otherwise cross-correlating signals. In a
9 preferred embodiment, such modulation techniques may be used,
10 allowing more efficient use of frequency spectrum and allowing
11 frequencies to be reused at closer proximity.

12 13 Alternative Embodiments

14
15 While preferred embodiments are disclosed herein, many
16 variations are possible which remain within the concept and scope
17 of the invention, and these variations would become clear to one
18 of ordinary skill in the art after perusal of the specification,
19 drawings and claims herein.

20
21 For example, it would be clear to one of ordinary skill
22 in the art, after perusal of the specification, drawings and
23 claims herein, that other and further techniques, such as
24 adjustable power control, cell sectoring, directional antennas,
25 and antennae diversity, may be used to enhance a wireless
26 communication system embodying the principles of the invention.
27 Moreover, it would be clear to one of ordinary skill that a
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1 system also employing such other and further techniques would be
2 workable, and is within the scope and spirit of the invention.

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